

Chapter 6 Sump Design

6-1. General

Rectangular wet pit and the formed suction intake (FSI) are the two basic sump types most commonly used in civil works pumping stations.

a. Rectangular wet pit. In the past, the rectangular wet-pit sump with the conventional pump bell-mouth inlet was the most common type used. Experience has shown, however, that the sump's hydraulic performance is very sensitive to inflow conditions, sump design, and pump operation. Appendix B, Chart B-2, of EM 1110-2-3105 provides sump design guidance.

b. FSI. The FSI was developed in the early 1990's by the WES Hydraulics Laboratory. The FSI has demonstrated the ability to improve the poor hydraulic sump performance sometimes experienced with the rectangular wet-pit sump. Detailed design guidance for the FSI is provided in Appendix I of EM 1110-2-3105. A pump station equipped with an FSI is shown in Plates 8 and 9.

6-2. Size and Capacity Determination

a. Sump levels. Maximum water surface elevation in the sump of stations pumping from sewers will be fixed by project damage elevation, by the hydraulic gradient between the protected area and the pumping station, and by the condition of the particular sewer. For stations pumping from ponding areas, the maximum water surface elevation of the sump will be fixed by the maximum permissible ponding elevation. For sewers subject to structural damage from fluctuating water pressure, such as old brick sewers in questionable condition, and sewers which are inadequate to pass the design storm runoff, the maximum sump operating level should be restricted to the elevation of the crown of the sewer at the point of entrance to the sump. For a well-designed and well-constructed sewer, the maximum sump operating level may fall above the crown of the sewer, subject to consideration of the level of the hydraulic gradient with respect to "no damage" level along the sewer. The station-operating floor elevation should be no lower than 1 ft above the maximum water surface elevation in the sump. The sump shall be kept dry either by gravity drainage or by sump pump(s). If the period of gravity drainage occurs less than 50 percent of the nonpumping period, then sump pumps should be provided to dewater the station's sump. The minimum water surface elevation

in the sump is determined by the hydraulic and protection requirements of the protected area and economic considerations. This minimum sump elevation affects the station design and pumping equipment characteristics.

b. Minimum sump area. Minimum horizontal sump area will be that required to permit adequate spacing of pumps and intake systems to provide adequate space for installation of discharge and suction lines and associated equipment and flows to the pumps. Sump area based on these requirements normally will be adequate unless it is found desirable to increase the horizontal area of the sump either to provide more sump storage volume to obtain acceptable minimum pump operating cycles, or to alleviate surges caused by pump shutdown in the sump and connecting sewers.

c. Determination of sump dimensions. The dimensions and general layout of the sump must fulfill a number of requirements. Primarily, the selected design must provide adequate horizontal and vertical clearance and adequate approach conditions for the pumps to be used. Important layout and dimensional requirements for satisfactory pump performance are as follows:

(1) Horizontal clearances for rectangular wet-pit sumps are generally satisfied if the distance between centerlines of adjacent pumps is equal to the sum of the suction bell diameters (plus the thickness of the divider wall), and if the centerline of each pump is at least one suction bell diameter away from the nearest sump side wall and three-fourths of a suction bell diameter from the rear wall. The use of suction umbrellas does not change the above clearances. In general, the diameter of a propeller pump's suction bell (no umbrella) is around 1.5 to 1.6 times the nozzle inlet diameter. (Appendix B, Chart B-2, of EM 1110-2-3105 may be used for these dimensions.)

(2) The principal factors involved in the determination of submergence and vertical clearance requirements are cavitation limits and the means to preclude the formation of sustained vortices. Chart B-2, referenced above, should be followed for these dimensions.

(3) Cavitation can be reasonably predicted from the computational procedure in Appendix B of EM 1110-2-3105. This procedure computes the required submergence based on test results of pumps at Corps pumping stations. A submergence allowance is used to obtain greater submergence for pumping stations with long periods of operation. The impeller should always be completely submerged at the start of pumping.

(4) Vortex formation can be minimized by controlling the flow conditions into the sump and to the pump. Station layout dimensions and ratios provided in Appendix B of EM 1110-2-3105 along with straight inflow to the station intake should eliminate or reduce the intensity of vortices. If the station cannot be laid out to these dimensions and straight inflow does not occur, then either a sump model test should be considered or the FSI incorporated into the design. The FSI has demonstrated the ability to nearly eliminate vortexing at the pump.

d. Sump layout.

(1) The best flow conditions are obtained when the water approaches the pump from all directions with as uniform a velocity as possible and with minimum disturbance from the flow toward other units. The placing of the sump intake to provide as near equal flow distances as possible to the pumps is a good start toward satisfactory sump flow conditions.

(2) Whenever station layout permits, an intake gate should be provided in front of each pump. Velocity through intake gates must be coordinated with the sump drawdown or operating range. In general, the velocity through intake gates should be as low as possible provided no special requirements or excessive increased costs are involved. In no case should the velocity through the gate be greater than 1.5 m/sec (5 fps). Abrupt changes in direction and velocity of flow should be avoided.

(3) Sump design and layout will be based on established Corps guidance. However, if the pump manufacturer disagrees with the Corps' design and proves, through model testing, a better design, then the contractor's design should be used and the contractor held responsible for the sump design.

e. Sump capacity.

(1) In addition to the above-mentioned requirements for satisfactory pump operation, the station design should include a determination of the water volume between maximum and minimum operating elevations that will permit acceptable minimum pump operating cycles. This water volume would include the capacity of the sump, trash rack chamber, interconnecting sewer, or ponding area. Sufficient storage is provided between the pump's starting and stopping elevations when the starting of any one pump will not be required more often than once in 15 min or a cycle as recommended by the motor manufacturer. An inflow rate equal to one-half of the pumping rate of the pump should be assumed, as this inflow will cause the most frequent number of repeated starts and

stops of the pump. Storage required above the stop elevation to ensure a minimum interval as indicated above between successive starts of a given pump is usually not possible. Since the maximum sump operating level is usually fixed by the project damage elevation or other considerations, any required increase in sump capacity can be accomplished only by lowering the sump floor. A gain in sump capacity by lowering the sump floor is usually attended by increased pumping power requirements. An increase in sump area will probably cause adverse flow to pumps and therefore cannot be used. A variable speed pump drive should be considered since on-off cycles and surges when the unit is stopped can be eliminated by its use.

(2) The use of bypasses gains equivalent sump capacity during periods of pump operation with small inflows and accomplishes that function by decreasing the net effective discharge of pumps operating. Bypasses should be considered where space and structural requirements cannot be changed and sump capacity is inadequate to: prevent excessively frequent starting of pumps, particularly where failure of one pump of a group operated on programmed control is a possibility; compensate for a lag in the inflow from a sewer; and prevent surges in sewers and sumps which would be caused by rapid lowering and then raising of sump levels.

(3) Bypasses may be located so as to permit return flow from riverside discharge chambers into the sump, or direct flow from a pump discharge line into the sump at a point between the pump and its discharge. With the former arrangement, the bypass is effective regardless of which pump is operated. The latter arrangement is used where pump discharge lines pass over levees and require a bypass on each pump or a number of pumps to ensure satisfactory bypass capacity when any pump is out of service.

(4) Where a single bypass from the discharge chamber to the sump is to be installed, its capacity at minimum head and maximum operating sump water elevations should be at least equal to the capacity of the largest incremental change in discharge capacity. When a bypass is located on a pump discharge line, its capacity under the same conditions of head should be sufficient to provide the desired operating cycle, usually one-half the capacity of the largest pump. In both cases, the increased capacity of pumps at lower than design heads should be recognized. Butterfly valves are normally used to control the bypass flow. These valves are provided with power operators when manual operation requires more than a 110-N (25-lb) pull on the valve operator.

(5) The determination of sump capacity requires close coordination with the entire design of the pumping station. Basic factors such as type of prime mover, number and size of pumps, and size and arrangement of station are affected by, or have an effect on, sump capacity. Selection of design to provide adequate sump capacity should be based on a comparison of overall cost for each installation. Factors to be considered include cost of sump structure and superstructure, higher price of equipment accompanying any increase in pumping requirements, increased cost of variable-capacity in lieu of fixed-capacity pumps, and cost of operation.

6-3. Surges in Sump

a. General. Surges may occur in pipelines which flow full and are subject to sudden changes in rate of discharge. This is possible where the sump area and adjacent areas have too small a water volume. Serious damage could occur if proper consideration is not given to the effects of surges in designing the pump station. Surges and resulting rapid fluctuations of the water surface elevations in the sump could also affect the proper operation of the automatic stop controls of the pump. The condition of a surcharged pipeline discharging to a pump station sump may be considered somewhat analogous to the penstock and surge tank of a hydroelectric powerplant. HDC should be consulted under these conditions.

b. Amount of surge. The height to which the water will surge in the pump sump is a function of the length of a pipeline flowing full, the cross-sectional area of the pipeline, the volume of the sump, the change in pump discharge, and the friction losses. An exact mathematical solution of the problem is often practically impossible because of the many changes in pipe size and the numerous inlet points on a sewer system. However, approximate methods, developed by HDC, permit mathematical treatment of the problem and give results sufficiently accurate for design purposes.

c. Provisions for protection against surge. Certain features inherent in the design of pumping stations and sewer systems automatically supply a dampening effect on surges. Various laterals and manholes of the sewer system, the operating sump, and intake and trash rack wells act as surge tanks. Use of adjustable-blade pumps or variable-speed motors will allow gradual reduction of pump discharge upon shutdown and would reduce operational difficulties arising from surges. In cases where the surge will be great, consideration of one of the following methods will aid in solving the problem.

(1) Raise the operating floor of the pumping station above ground level and provide overflow openings below the station floor. In order to confine the effluent and facilitate its removal, a catch basin would have to be constructed adjacent to the forebay, with a gravity drain to return the overflow to the station. This method would protect the station from damage due to extremely large surges that might be caused by total station shutdown, but ordinarily would not alleviate the smaller surges due to shutdown of single pumps, which may cause operational difficulties.

(2) Stations having the operating floor above the high-water elevation or located outside the line of protection may have flap-gated bypasses from the station sump pump intake to a pressure discharge chamber or directly into the stream. This arrangement might require changes in the station design, particularly in the design of the operating floor which may be subject to upward pressures. This method can be used to protect the station from extremely large surges. The effectiveness of the method in reducing smaller surges would be dependent upon the elevation of the water surface in the discharge chamber or in the stream at the start of the surge and upon the elevation at which the bypasses are placed.

(3) The horizontal cross-sectional area of the inflow sump could be increased to act as a surge tank. The sump dimensions should not be increased above that area required for proper sump flow.

(4) A special surge tank or a surge basin could be used at some point on the pipeline near the pumping station. The effectiveness of this method is dependent upon the horizontal cross-sectional area provided by the elevation at which the surge tank becomes effective. This method is effective in reducing all surges, both in the sump and in the connecting sewer. However, for greatest effect at the pumping station, the surge tank or surge basin should be placed as close to the station as practicable.

(5) For a large pipeline, an initial intake sump could be provided with a regulating weir into a second sump at one side in order to maintain a constant hydraulic gradient in the sewer. This method would prevent surges from moderate changes in pump discharge but may not greatly affect large surges resulting from total station shutdown and may not afford sufficient protection for the pumping station.

6-4. Trash Racks

a. Racks. Except for stations of minor importance and sewage-type pumping stations, all flows into flood protection pumping stations should be screened before reaching the pumps. Conventional bar screens (trash racks) are the preferred method of screening. Suction strainers should be avoided as they clog readily and are difficult to clean. Trash racks must be located to allow incoming flows to pass through the rack before reaching any pump intake, flow to be evenly distributed over the submerged rack surface, and raking to be accomplished coincident with pump operation. Trash racks located in the sewer which flows by the pumping station should be readily removable, and minimal means should be provided to allow the racks to be raised above the maximum sump level and secured when the station is not in use. Trash racks should always be located outside the station superstructure in order that operating areas are not exposed to

the moisture and fumes usually present during raking operations, and to facilitate disposal of trash accumulations. Where flows are adequately screened prior to entry into the collecting system by grated catch basins or other methods, trash racks need not always be provided. However, omission of trash racks must be based upon sound engineering judgment and economic considerations and must be justified and explained in the design analysis.

b. Effective areas and bar spacing. Trash racks should have ample net area so that the velocity of the flow through the gross rack area does not exceed 0.76 m/sec (2.5 fps). The clear opening between bars should be approximately 45 mm (1-3/4 in.), but may be greater if justified by the size and type of pumps to be protected, but should not exceed 75 mm (3 in.) in any case. Bar spacing should be coordinated with the pump manufacturer.